

## 3.E: Atoms, Molecules, and Ions (Exercises)

### Exercises (Atomic Theory)

- List the three statements that make up the modern atomic theory.
- Explain how atoms are composed.
- Which is larger, a proton or an electron?
- Which is larger, a neutron or an electron?
- What are the charges for each of the three subatomic particles?
- Where is most of the mass of an atom located?
- Sketch a diagram of a boron atom, which has five protons and six neutrons in its nucleus.
- Sketch a diagram of a helium atom, which has two protons and two neutrons in its nucleus.
- Define *atomic number*. What is the atomic number for a boron atom?
- What is the atomic number of helium?
- Define *isotope* and give an example.
- What is the difference between deuterium and tritium?
- Which pair represents isotopes?
  - ${}^4_2\text{He}$  and  ${}^3_2\text{He}$
  - ${}^{56}_{26}\text{Fe}$  and  ${}^{56}_{25}\text{Mn}$
  - ${}^{28}_{14}\text{Si}$  and  ${}^{31}_{15}\text{P}$
- Which pair represents isotopes?
  - ${}^{40}_{20}\text{Ca}$  and  ${}^{40}_{19}\text{K}$
  - ${}^{56}_{26}\text{Fe}$  and  ${}^{56}_{28}\text{Fe}$
  - ${}^{238}_{92}\text{U}$  and  ${}^{235}_{92}\text{U}$
- Give complete symbols of each atom, including the atomic number and the mass number.
  - an oxygen atom with 8 protons and 8 neutrons
  - a potassium atom with 19 protons and 20 neutrons
  - a lithium atom with 3 protons and 4 neutron
- Give complete symbols of each atom, including the atomic number and the mass number.
  - a magnesium atom with 12 protons and 12 neutrons
  - a magnesium atom with 12 protons and 13 neutrons
  - a xenon atom with 54 protons and 77 neutron
- Americium-241 is an isotope used in smoke detectors. What is the complete symbol for this isotope?
- Carbon-14 is an isotope used to perform radioactive dating tests on previously living material. What is the complete symbol for this isotope?

Give atomic symbols for each element.

  - sodium
  - argon
  - nitrogen
  - radon
- Give atomic symbols for each element.
  - silver

- b. gold
- c. mercury
- d. iodine

20. Give the name of the element.

- a. Si
- b. Mn
- c. Fe
- d. Cr

21. Give the name of the element.

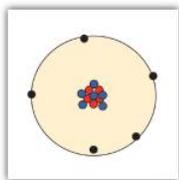
- a. F
- b. Cl
- c. Br
- d. I

### Answers

1. All matter is composed of atoms; atoms of the same element are the same, and atoms of different elements are different; atoms combine in whole-number ratios to form compounds.

3. A proton is larger than an electron.

5. proton: 1+; electron: 1-; neutron: 0



7.

9. The atomic number is the number of protons in a nucleus. Boron has an atomic number of five.

11. Isotopes are atoms of the same element but with different numbers of neutrons.  ${}^1_1\text{H}$  and  ${}^2_1\text{H}$

13.

- a. isotopes
- b. not isotopes
- c. not isotopes

15.

- a.  ${}^{16}_8\text{O}$
- b.  ${}^{39}_{19}\text{K}$
- c.  ${}^7_3\text{Li}$

17.  ${}_{95}^{241}\text{Am}$

19.

- a. Na
- b. Ar
- c. N
- d. Rn

21.

- a. silicon
- b. manganese

- c. iron
- d. chromium

### Exercises (Molecules and Chemical Nomenclature)

1. Which of these formulas represent molecules? State how many atoms are in each molecule.
  - a. Fe
  - b.  $\text{PCl}_3$
  - c.  $\text{P}_4$
  - d. Ar
  
2. Which of these formulas represent molecules? State how many atoms are in each molecule.
  - a.  $\text{I}_2$
  - b. He
  - c.  $\text{H}_2\text{O}$
  - d. Al
  
3. What is the difference between CO and Co?
  
4. What is the difference between  $\text{H}_2\text{O}$  and  $\text{H}_2\text{O}_2$  (hydrogen peroxide)?
  
5. Give the proper formula for each diatomic element.
  
6. In 1986, when Halley's comet last passed the earth, astronomers detected the presence of  $\text{S}_2$  in their telescopes. Why is sulfur not considered a diatomic element?
  
7. What is the stem of fluorine used in molecule names?  $\text{CF}_4$  is one example.
  
8. What is the stem of selenium used in molecule names?  $\text{SiSe}_2$  is an example.
  
9. Give the proper name for each molecule.
  - a.  $\text{PF}_3$
  - b.  $\text{TeCl}_2$
  - c.  $\text{N}_2\text{O}_3$
  
10. Give the proper name for each molecule.
  - a. NO
  - b.  $\text{CS}_2$
  - c.  $\text{As}_2\text{O}_3$
  
11. Give the proper name for each molecule.
  - a.  $\text{XeF}_2$
  - b.  $\text{O}_2\text{F}_2$
  - c.  $\text{SF}_6$
  
12. Give the proper name for each molecule.
  - a.  $\text{P}_4\text{O}_{10}$
  - b.  $\text{B}_2\text{O}_3$
  - c.  $\text{P}_2\text{S}_3$
  
13. Give the proper name for each molecule.
  - a.  $\text{N}_2\text{O}$
  - b.  $\text{N}_2\text{O}_4$
  - c.  $\text{N}_2\text{O}_5$

14. Give the proper name for each molecule.

- a.  $\text{SeO}_2$
- b.  $\text{Cl}_2\text{O}$
- c.  $\text{XeF}_6$

15. Give the proper formula for each name.

- a. dinitrogen pentoxide
- b. tetraboron tricarbide
- c. phosphorus pentachloride

16. Give the proper formula for each name.

- a. nitrogen triiodide
- b. diarsenic trisulfide
- c. iodine trichloride

17. Give the proper formula for each name.

- a. dioxygen dichloride
- b. dinitrogen trisulfide
- c. xenon tetrafluoride

18. Give the proper formula for each name.

- a. chlorine dioxide
- b. selenium dibromide
- c. dinitrogen trioxide

19. Give the proper formula for each name.

- a. iodine trifluoride
- b. xenon trioxide
- c. disulfur decafluoride

20. Give the proper formula for each name.

- a. germanium dioxide
- b. carbon disulfide
- c. diselenium dibromide

### Answers

1.
  - a. not a molecule
  - b. a molecule; four atoms total
  - c. a molecule; four atoms total
3. CO is a compound of carbon and oxygen; Co is the element cobalt.
5.  $\text{H}_2$ ,  $\text{O}_2$ ,  $\text{N}_2$ ,  $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$ ,  $\text{I}_2$
7. *fluor-*
9.
  - a. phosphorus trifluoride
  - b. tellurium dichloride
  - c. dinitrogen trioxide
11.
  - a. xenon difluoride

- b. dioxygen difluoride
- c. sulfur hexafluoride

13.

- a. dinitrogen monoxide
- b. dinitrogen tetroxide
- c. dinitrogen pentoxide

15.

- a.  $\text{N}_2\text{O}_5$
- b.  $\text{B}_4\text{C}_3$
- c.  $\text{PCl}_5$

17.

- a.  $\text{O}_2\text{Cl}_2$
- b.  $\text{N}_2\text{S}_3$
- c.  $\text{XeF}_4$

19.

- a.  $\text{IF}_3$
- b.  $\text{XeO}_3$
- c.  $\text{S}_2\text{F}_{10}$

### Exercises (Masses of Atoms and Molecules)

1. Define *atomic mass unit*. What is its abbreviation?
2. Define *atomic mass*. What is its unit?
3. Estimate the mass, in whole numbers, of each isotope.
  - a. hydrogen-1
  - b. hydrogen-3
  - c. iron-56
4. Estimate the mass, in whole numbers, of each isotope.
  - a. phosphorus-31
  - b. carbon-14
  - c. americium-241
5. Determine the atomic mass of each element, given the isotopic composition.
  - a. lithium, which is 92.4% lithium-7 (mass 7.016 u) and 7.60% lithium-6 (mass 6.015 u)
  - b. oxygen, which is 99.76% oxygen-16 (mass 15.995 u), 0.038% oxygen-17 (mass 16.999 u), and 0.205% oxygen-18 (mass 17.999 u)
6. Determine the atomic mass of each element, given the isotopic composition.
  - a. neon, which is 90.48% neon-20 (mass 19.992 u), 0.27% neon-21 (mass 20.994 u), and 9.25% neon-22 (mass 21.991 u)
  - b. uranium, which is 99.27% uranium-238 (mass 238.051 u) and 0.720% uranium-235 (mass 235.044 u)
7. How far off would your answer be from Exercise 5a if you used whole-number masses for individual isotopes of lithium?

8. How far off would your answer be from Exercise 6b if you used whole-number masses for individual isotopes of uranium?
9. a. What is the atomic mass of an oxygen atom?  
b. What is the molecular mass of oxygen in its elemental form?
10. a. What is the atomic mass of bromine?  
b. What is the molecular mass of bromine in its elemental form?
11. Determine the mass of each substance.  
a. F<sub>2</sub>  
b. CO  
c. CO<sub>2</sub>
12. Determine the mass of each substance.  
a. Kr  
b. KrF<sub>4</sub>  
c. PF<sub>5</sub>
13. Determine the mass of each substance.  
a. Na  
b. B<sub>2</sub>O<sub>3</sub>  
c. S<sub>2</sub>Cl<sub>2</sub>
14. Determine the mass of each substance.  
a. IBr<sub>3</sub>  
b. N<sub>2</sub>O<sub>5</sub>  
c. CCl<sub>4</sub>
15. Determine the mass of each substance.  
a. GeO<sub>2</sub>  
b. IF<sub>3</sub>  
c. XeF<sub>6</sub>
16. Determine the mass of each substance.  
a. NO  
b. N<sub>2</sub>O<sub>4</sub>  
c. Ca

### Answers

1. The atomic mass unit is defined as one-twelfth of the mass of a carbon-12 atom. Its abbreviation is u.
3.  
a. 1  
b. 3  
c. 56
5.  
a. 6.940 u  
b. 16.000 u
7. We would get 6.924 u.

- 9.
- a. 15.999 u
  - b. 31.998 u
- 11.
- a. 37.996 u
  - b. 28.010 u
  - c. 44.009 u
- 13.
- a. 22.990 u
  - b. 69.619 u
  - c. 135.036 u
- 15.
- a. 104.64 u
  - b. 183.898 u
  - c. 245.281 u

### Exercises (Ions and Ionic Compounds)

1. Explain how cations form.
2. Explain how anions form.
3. Give the charge each atom takes when it forms an ion. If more than one charge is possible, list both.
  - a. K
  - b. O
  - c. Co
4. Give the charge each atom takes when it forms an ion. If more than one charge is possible, list both.
  - a. Ca
  - b. I
  - c. Fe
5. Give the charge each atom takes when it forms an ion. If more than one charge is possible, list both.
  - a. Ag
  - b. Au
  - c. Br
6. Give the charge each atom takes when it forms an ion. If more than one charge is possible, list both.
  - a. S
  - b. Na
  - c. H
7. Name the ions from Exercise 3.
8. Name the ions from Exercise 4.
9. Name the ions from Exercise 5.

10. Name the ions from Exercise 6.
11. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{Mg}^{2+}$  and  $\text{Cl}^-$
  - $\text{Fe}^{2+}$  and  $\text{O}^{2-}$
  - $\text{Fe}^{3+}$  and  $\text{O}^{2-}$
12. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{K}^+$  and  $\text{S}^{2-}$
  - $\text{Ag}^+$  and  $\text{Br}^-$
  - $\text{Sr}^{2+}$  and  $\text{N}^{3-}$
13. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{Cu}^{2+}$  and  $\text{F}^-$
  - $\text{Ca}^{2+}$  and  $\text{O}^{2-}$
  - $\text{K}^+$  and  $\text{P}^{3-}$
14. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{Na}^+$  and  $\text{N}^{3-}$
  - $\text{Co}^{2+}$  and  $\text{I}^-$
  - $\text{Au}^{3+}$  and  $\text{S}^{2-}$
15. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{K}^+$  and  $\text{SO}_4^{2-}$
  - $\text{NH}_4^+$  and  $\text{S}^{2-}$
  - $\text{NH}_4^+$  and  $\text{PO}_4^{3-}$
16. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{Ca}^{2+}$  and  $\text{NO}_3^-$
  - $\text{Ca}^{2+}$  and  $\text{NO}_2^-$
  - $\text{Sc}^{3+}$  and  $\text{C}_2\text{H}_3\text{O}_2^-$
17. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{Pb}^{4+}$  and  $\text{SO}_4^{2-}$
  - $\text{Na}^+$  and  $\text{I}_3^-$
  - $\text{Li}^+$  and  $\text{Cr}_2\text{O}_7^{2-}$
18. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{NH}_4^+$  and  $\text{N}^{3-}$
  - $\text{Mg}^{2+}$  and  $\text{CO}_3^{2-}$
  - $\text{Al}^{3+}$  and  $\text{OH}^-$
19. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{Ag}^+$  and  $\text{SO}_3^{2-}$
  - $\text{Na}^+$  and  $\text{HCO}_3^-$
  - $\text{Fe}^{3+}$  and  $\text{ClO}_3^-$
20. Give the formula and name for each ionic compound formed between the two listed ions.
- $\text{Rb}^+$  and  $\text{O}_2^{2-}$

- b.  $\text{Au}^{3+}$  and  $\text{HSO}_4^-$
- c.  $\text{Sr}^{2+}$  and  $\text{NO}_2^-$

21. What is the difference between  $\text{SO}_3$  and  $\text{SO}_3^{2-}$ ?

22. What is the difference between  $\text{NO}_2$  and  $\text{NO}_2^-$ ?

### Answers

1. Cations form by losing electrons.

3.

- a. 1+
- b. 2-
- c. 2+, 3+

5.

- a. 1+
- b. 1+, 3+
- c. 1-

7.

- a. the potassium ion
- b. the oxide ion
- c. the cobalt(II) and cobalt(III) ions, respectively

9.

- a. the silver ion
- b. the gold(I) and gold(III) ions, respectively
- c. the bromide ion

11.

- a. magnesium chloride,  $\text{MgCl}_2$
- b. iron(II) oxide,  $\text{FeO}$
- c. iron(III) oxide,  $\text{Fe}_2\text{O}_3$

13.

- a. copper(II) fluoride,  $\text{CuF}_2$
- b. calcium oxide,  $\text{CaO}$
- c. potassium phosphide,  $\text{K}_3\text{P}$

15.

- a. potassium sulfate,  $\text{K}_2\text{SO}_4$
- b. ammonium sulfide,  $(\text{NH}_4)_2\text{S}$
- c. ammonium phosphate,  $(\text{NH}_4)_3\text{PO}_4$

17.

- a. lead(IV) sulfate,  $\text{Pb}(\text{SO}_4)_2$
- b. sodium triiodide,  $\text{NaI}_3$
- c. lithium dichromate,  $\text{Li}_2\text{Cr}_2\text{O}_7$

19.

- a. silver sulfite,  $\text{Ag}_2\text{SO}_3$
- b. sodium hydrogen carbonate,  $\text{NaHCO}_3$
- c. iron(III) chlorate,  $\text{Fe}(\text{ClO}_3)_3$

21.  $\text{SO}_3$  is sulfur trioxide, while  $\text{SO}_3^{2-}$  is the sulfite ion.

### Exercises (Acids)

1. Give the formula for each acid.
  - a. perchloric acid
  - b. hydriodic acid
2. Give the formula for each acid.
  - a. hydrosulfuric acid
  - b. phosphorous acid
3. Name each acid.
  - a.  $\text{HF}(\text{aq})$
  - b.  $\text{HNO}_3(\text{aq})$
  - c.  $\text{H}_2\text{C}_2\text{O}_4(\text{aq})$
4. Name each acid.
  - a.  $\text{H}_2\text{SO}_4(\text{aq})$
  - b.  $\text{H}_3\text{PO}_4(\text{aq})$
  - c.  $\text{HCl}(\text{aq})$
5. Name an acid found in food.
6. Name some properties that acids have in common.

### Answers

1.
  - a.  $\text{HClO}_4(\text{aq})$
  - b.  $\text{HI}(\text{aq})$
3.
  - a. hydrofluoric acid
  - b. nitric acid
  - c. oxalic acid
5. oxalic acid (answers will vary)

### Additional Exercises

1. How many electrons does it take to make the mass of one proton?
2. How many protons does it take to make the mass of a neutron?
3. Dalton's initial version of the modern atomic theory says that all atoms of the same element are the same. Is this actually correct? Why or why not?
4. How are atoms of the same element the same? How are atoms of the same element different?
5. Give complete atomic symbols for the three known isotopes of hydrogen.
6. A rare isotope of helium has a single neutron in its nucleus. Write the complete atomic symbol of this isotope.
7. Use its place on the periodic table to determine if indium, In, atomic number 49, is a metal or a nonmetal.
8. Only a few atoms of astatine, At, atomic number 85, have been detected. On the basis of its position on the periodic table, would you expect it to be a metal or a nonmetal?

9. Americium-241 is a crucial part of many smoke detectors. How many neutrons are present in its nucleus?
10. Potassium-40 is a radioactive isotope of potassium that is present in the human body. How many neutrons are present in its nucleus?
11. Determine the atomic mass of ruthenium from the given abundance and mass data.

Ruthenium-96	5.54%	95.907 u
Ruthenium-98	1.87%	97.905 u
Ruthenium-99	12.76%	98.906 u
Ruthenium-100	12.60%	99.904 u
Ruthenium-101	17.06%	100.906 u
Ruthenium-102	31.55%	101.904 u
Ruthenium-104	18.62%	103.905 u

12. Determine the atomic mass of tellurium from the given abundance and mass data.

Tellurium-120	0.09%	119.904 u
Tellurium-122	2.55%	121.903 u
Tellurium-123	0.89%	122.904 u
Tellurium-124	4.74%	123.903 u
Tellurium-125	7.07%	124.904 u
Tellurium-126	18.84%	125.903 u
Tellurium-128	31.74%	127.904 u
Tellurium-130	34.08%	129.906 u

13. One atomic mass unit has a mass of  $1.6605 \times 10^{-24}$  g. What is the mass of one atom of sodium?
14. One atomic mass unit has a mass of  $1.6605 \times 10^{-24}$  g. What is the mass of one atom of uranium?
15. One atomic mass unit has a mass of  $1.6605 \times 10^{-24}$  g. What is the mass of one molecule of  $\text{H}_2\text{O}$ ?
16. One atomic mass unit has a mass of  $1.6605 \times 10^{-24}$  g. What is the mass of one molecule of  $\text{PF}_5$ ?
17. From their positions on the periodic table, will Cu and I form a molecular compound or an ionic compound?
18. From their positions on the periodic table, will N and S form a molecular compound or an ionic compound?
19. Mercury is an unusual element in that when it takes a 1+ charge as a cation, it always exists as the diatomic ion.
- Propose a formula for the mercury(I) ion.
  - What is the formula of mercury(I) chloride?
20. Propose a formula for hydrogen peroxide, a substance used as a bleaching agent. (Curiously, this compound does not behave as an acid, despite its formula. It behaves more like a classic nonmetal-nonmetal, molecular compound.)
21. The uranyl cation has the formula  $\text{UO}_2^{2+}$ . Propose formulas and names for the ionic compounds between the uranyl cation and  $\text{F}^-$ ,  $\text{SO}_4^{2-}$ , and  $\text{PO}_4^{3-}$ .
22. The permanganate anion has the formula  $\text{MnO}_4^-$ . Propose formulas and names for the ionic compounds between the permanganate ion and  $\text{K}^+$ ,  $\text{Ca}^{2+}$ , and  $\text{Fe}^{3+}$ .

## Answers

1. about 1,800 electrons
3. It is not strictly correct because of the existence of isotopes.
5.  ${}^1_1\text{H}$ ,  ${}^2_1\text{H}$ , and  ${}^3_1\text{H}$
7. It is a metal.
9. 146 neutrons
11. 101.065 u
13.  $3.817 \times 10^{-23}$  g
15.  $2.991 \times 10^{-23}$  g
17. ionic
19.
  - a.  $\text{Hg}_2^{2+}$
  - b.  $\text{Hg}_2\text{Cl}_2$
21. uranyl fluoride,  $\text{UO}_2\text{F}_2$ ; uranyl sulfate,  $\text{UO}_2\text{SO}_4$ ; uranyl phosphate,  $(\text{UO}_2)_3(\text{PO}_4)_2$

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